Fracture resistance of thin-walled roots restored with different post systems

B. H. Kıvanç, T. Alaçam, Ö. İ. A. Ulusoy, Ö. Genç & G. Görgül

Department of Operative Dentistry and Endodontics, Faculty of Dentistry, University of Gazi, Ankara, Turkey

Abstract

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Aim To compare the fracture resistance of thin-walled roots after restoration with different types of post systems.

Methodology One hundred and sixty-five decoronated maxillary central incisors were root filled and randomly assigned to three groups with respect to the remaining dentine thickness of root (1.0 mm, 1.5 mm, 2.0 mm). Each group was randomly divided into five equal subgroups. The subgroups were restored with one of the following post systems: polyethylene woven fibre (R), composite resin cured by light-transmitting post + glass fibre post (L), electrical glass fibre post (E), composite corono-radicular restoration (C) and cast metal post (M). Standard cores were constructed using composite resin in the first four groups. The samples were subjected to a gradually increasing force (1 mm min^{-1}). The force required to fracture was recorded. The data was analysed with ANOVA and Tukey test ($P = 0.05$).

Results The cast metal post group had the highest fracture strength ($P < 0.001$). There was no significant difference in fracture resistance between the other four groups. Fracture resistance was affected largely by the remaining dentine thickness in fibre post groups; however, the difference was not significant. On the contrary in the cast metal post group load failure was inversely influenced by axio-proximal dimension of dentine walls.

Conclusion The cast post group had a higher fracture strength than resin groups. The force required to fracture the roots was similar for all fibre post systems and for all dentine thicknesses.

Keywords: fibre-reinforced composite post, Fracture resistance, thin-walled roots.

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Introduction

Post systems that can bond to root canal walls and possess mechanical properties closer to those of dentine have been developed to increase the fracture resistance of thin-walled teeth (Newman *et al.* 2003, Maccari *et al.* 2007). Pre-fabricated posts associated with resin reinforcement of the root walls have been used to increase fracture strength of flared canals (Saupe *et al.* 1996). Nevertheless, to date, there is still no consensus regarding the most suitable material and technique for restoring root filled teeth with enlarged root canals.

Glass-fibre resin post systems that are composed of unidirectional glass fibres embedded in a resin matrix are reported to reduce the risk of fractures of filled roots (Kalkan *et al.* 2006). The electrical glass fibre post is an alternative material that contains a mixture of SiO_2, CaO, B_2O_3, Al_2O_3, plus other oxides of alkali metals. Polyethylene woven fibres are materials that are used in the post space with adhesive resins and are also suggested to increase the fracture resistance of filled roots. With this woven fibre ribbon and commonly

Correspondence: Dr Bağdagül Helvacıoğlu Kıvanç, Department of Operative Dentistry and Endodontics, Faculty of Dentistry, Gazi University, 8. cd. 82. sk. 06510 Emek, Ankara, Turkey (Tel.: +90 312 203 41 23; e-mail: bagdagulkivanc@gmail.com; bagdagul@gazi.edu.tr)

available adhesive restorative materials, aesthetic dowels and core foundations can be made more easily (Üşümez *et al.* 2004).

Plastic, light-transmitting posts were developed for the purpose of light transmission to the circumferential composite resin used for building matrices around metallic posts and strengthening remaining root structures in excessively flared root canals (Lui 1994a). The use of a light-transmitting post within resin has been reported to increase the depth of resin cure (Lui 1994b). In traditional applications, after composite cure, the plastic post is removed and a metallic post with dimensions identical to the plastic post is inserted and cemented (Lui 1994b). However, instead of the original metal posts, fibre posts with similar dimensions could be chosen and applied as a core material inside all resin constructions (Yoldaş & Alaçam 2005).

The purpose of this study was to compare the fracture resistance of excessively flared roots with different dentine wall thicknesses that were restored using three different post systems, a composite coronoradicular restoration and a cast metal post.

Material and methods

One hundred and sixty-five freshly extracted, similar-sized intact human maxillary central incisor teeth were selected. The teeth were cleaned of debris and soft tissue remnants and examined stereoscopically at 10× magnification to verify absence of cracks. The teeth were stored in 0.1% thymol for less than 3 months at room temperature. The crown portion of each tooth was removed by cutting with a diamond bur (SS White Burs, NJ, USA) under water cooling below the cemento-enamel junction perpendicularly to the long axis of the tooth. To standardize the root canal lengths, the roots were shortened to a uniform length of 15 mm. The root canals were instrumented using the step-back technique at a working length of 1 mm from the apex to a size 55 (K-file, Antaeos, Munich, Germany). After intermittent rinsing with 2.5% NaOCl, the canals were dried with paper points (Union Broach Co, Long Island City, NY, USA) and filled with gutta-percha (Diadent, Seoul, Korea) and AH26 sealer (Denstply Maillefer, Ballaigues, Switzerland) using cold lateral compaction. Coronal gutta-percha was removed using the heat transferring instrument of the System B (EIE-Analytic Technology, Orange, CA, USA) and then Gates Glidden drills (nos. 2 and 3; Dentsply Maillefer) leaving 5 mm of material apically. Thus, large tapered post spaces were prepared to a depth of 10 mm in all teeth. The roots were then randomly assigned to three groups ($n = 55$). The post spaces were enlarged using tapered diamond burs (SS White Burs) leaving approximately 1.0 mm circumferential dentine in the first group, 1.5 mm in the second group and 2.0 mm in the third group at a point 2.5 mm below the cervical edge of the roots. Remaining dentine thickness was measured using an electronic measuring gauge (Fig. 1). These groups were randomly divided into five equal subgroups ($n = 11$, Groups R, L, E, C and M).

Group R

Polyethylene woven fibre (Ribbon, Ribbond Inc, Seattle, WA, USA) was applied to the bonded post spaces. The length of the post space was doubled, estimated core length added and necessary lengths of fibre were cut using special scissors. The ribbon material was soaked with unfilled resin (Clearfil SE Bond; Kuraray, Osaka, Japan). The self-etching primer (Clearfil SE Bond Primer; Kuraray) was applied to dowel space walls for 30 s and gently air dried. Adhesive (Clearfil SE Bond) was applied to the walls and thinned with a brush and light-cured for 20 s. A dual-polymerizing composite luting agent (Panavia F; Kuraray) was prepared and inserted into the dowel spaces using a lentulo spiral. The woven fibre saturated with a bonding agent was wrapped and condensed tightly into the canal space with an endodontic plugger. Excess resin was removed and free ends of the fibre were twisted and condensed into the canal. The entire fibre resin post was then cured for 40 s.

Group L

The primer and adhesive applications to dentinal surfaces were carried out in a similar process as in Group R. The root canal space was filled with composite (Clearfil Majesty Esthetic; Kuraray), and a light-transmitting plastic post (No. 3, Luminex, Dentatus AB; Stockholm, Sweden) was then inserted into the composite resin material up to the apical root filling. The composite was then light polymerized for 40 s, and thereafter, the plastic post was removed from the canal leaving an internal core space. The pre-fabricated glass fibre post (Mirafit White, Hager & Werken; Duisburg, Germany) was then prepared for application in this space. The coronal part of the glass fibre post (1.35×20 mm) was marked at the point of 13 mm from the apical end and cut by using water-cooled diamond bur to standardize the lengths. The internal
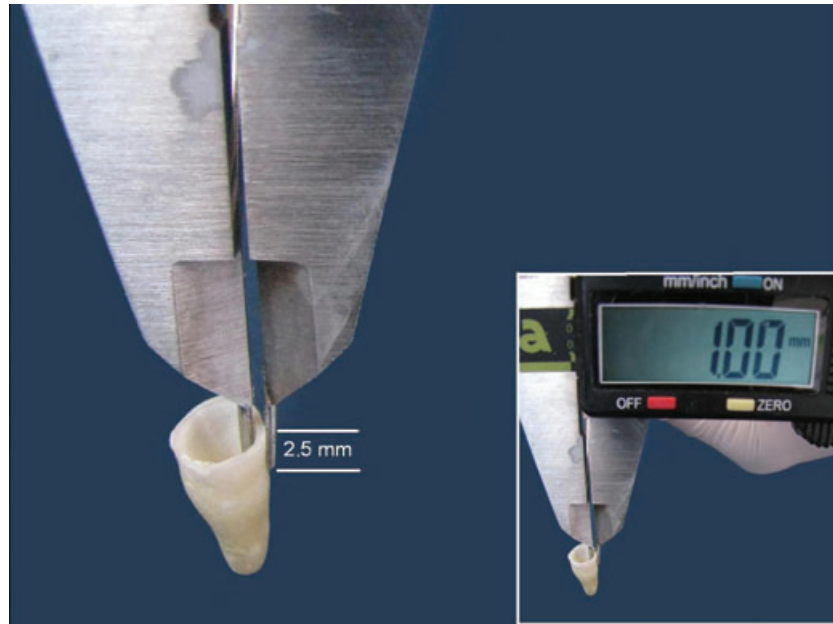
Figure 1 Measuring remaining dentine thickness using an electronic measuring gauge.

post space was filled with a dual-cure polymerized composite luting agent (Panavia F) using a lentulo spiral. A thin layer of cement was also coated on the post surface and the post was applied to the space with gentle pressure. Excess cement was removed and the remainder was light-cured for 40 s.

Group E

Electrical glass fibre post (everStick Posts, Stick Tech Ltd, Turku, Finland) was applied to the bonded post spaces. A suitable length of fibre was cut and the material was fitted to the root canal and further adapted to the cavity by gently pressing with a plugger. The whole system was light-cured for 20 s. Then the polymerized material was removed from the canal and light-cured once more on the outside from all sides for 40 s. The coronal part of each post was then marked and cut using a water-cooled diamond bur at the point 13 mm from the apical end. The primer and adhesive applications to dentinal surfaces were identical to that of Groups L and R. The surfaces of the posts were coated with resin adhesive (Clearfil SE Bond). After removal of the excess resin adhesive, the posts were luted into the post space and light-cured for 40 s.

Group C

A composite corono-radicular restoration was placed. The primer and adhesive applications to dentinal surfaces were accomplished in a similar manner to that used in Groups L, R and E. Composite (Clearfil Majesty Esthetic) and light-transmitting post (No. 3, Luminex) was inserted and polymerized like group L. The plastic post was removed and the remaining hole inside the root was filled with autopolymerized composite resin (Clearfil F II; Kuraray) condensed by endodontic pluggers.

Standard cores were then made with a composite resin (Clearfil Photocore; Kuraray) and core build-ups (Kuraray) in Groups R, L, E and C.

Group M

A cast metal post obtained by direct modelling with a pre-fabricated acrylic post-core pattern (Pin-Jet, Angelus; Londrina, PR, Brazil) was adjusted to the prepared root canal with Duralay acrylic resin (Reliance Dental Manufacturing Company, Chicago, IL, USA). The final resin pattern had an intraradicular portion with passive taper, and the coronal portion was made by acrylic resin using core build-ups. These resin patterns were cast with Ni-Cr alloy.

The restored teeth were stored in saline solution at 37 °C for 1 week. Plastic rings were filled with an autopolymerizing resin (Meliodent, Bayer Dental, Newbury, UK), and all teeth were embedded into the resin up to the level of the cemento-enamel junction. The plastic rings were then placed into a universal testing machine (Autograph AG-10 kNIS, Shimadzu, Kyoto,

Japan) and subjected to a compressive load on the palatal edge of the cores at an angle of 45 degrees to the long axis of the tooth. The load was applied at a crosshead speed of 1 mm min^{-1} until fracture occurred. The loads at the time of failure were recorded. Data were analysed by univariate analysis of variance (ANOVA) and Tukey tests for *post hoc* pairwise multiple comparisons at a significance level set at $\alpha = 0.05$.

Results

The results of the mean failure values (N) and standard deviations for the groups are shown in Table 1. For the 1.0 mm canal groups, the mean load value required to produce failure ranged from a low of 539.18 (± 196.430) for the composite corono-radicular restoration group to a high of 1708.73 (± 602.648) for the cast metal post group. For the 1.5 mm canal groups, the mean load value required to produce failure ranged from a low of 568.36 (± 71.742) for the composite corono-radicular restoration group to a high of 1659.36 (± 451.972) for the cast metal post group. For the 2.0 mm canal groups, the mean load value required to produce failure ranged from a low of 511.18 (± 122.296) for the composite corono-radicular restoration group to a high of 1220.18 (± 326.613) for the cast metal post group. The teeth restored with cast metal posts had higher fracture strength than teeth restored with fibre posts and all composite corono-radicular restoration ($P < 0.001$). There was no significant difference in fracture resistance between

Table 1 Failure loads for different materials at various remaining dentin thicknesses (Newton)

Group	N	Mean	SD	Difference
C2	11	511.18	122.296	a
C1	11	539.18	196.430	a
L1	11	557.82	181.674	a
E1	11	562.18	144.032	a
C1.5	11	568.36	71.742	a
L1.5	11	593.97	227.331	a
R1	11	603.55	150.201	a
R1.5	11	659.78	354.446	a
E1.5	11	708.93	308.609	a
L2	11	838.45	317.379	ab
R2	11	882.89	208.298	ab
E2	11	938.36	226.220	ab
M2	11	1220.18	326.613	b
M1.5	11	1659.36	451.972	cd
M1	11	1708.73	602.648	d

There was a significant difference between the materials ($P < 0.05$).
Different alphabets indicate difference between the groups.

the different fibre post materials and all composite corono-radicular restoration ($P > 0.05$), however, the composite corono-radicular restoration group yielded lower values. Fracture resistance was mainly affected by the remaining dentine thickness in fibre post groups; however, the difference did not reach statistical significance ($P > 0.05$). Contrary, in the cast metal post group load failure was inversely influenced by the axio-proximal dimensions of the walls. The cast metal posts with remaining dentine thickness of 2.0 mm yielded lower values than that of 1.0 mm and 1.5 mm ($P < 0.05$). In the 2.0 mm group, there was a significant difference between the cast metal post group and the composite corono-radicular restoration group ($P < 0.05$), contrary to indifference between the cast metal post group and polyethylene woven fibre, composite resin cured by light-transmitting post + glass fibre, electrical glass fibre post groups ($P > 0.05$).

Discussion

The aim of this study was to compare the fracture resistance of excessively flared roots with different remaining dentine wall thickness that were restored using three different fibre-reinforced composite post systems, a composite corono-radicular restoration and a traditional cast metal post.

There is much concern regarding whether or not to treat teeth that have badly broken-down and funnel-shaped canals with thin walls. Using *ex vivo* tests to evaluate the performance of post materials is one way to assess their effectiveness. Although the test standards and conditions are not identical to the clinical situation, they allow the comparison of different materials within a given standard (Varela *et al.* 2003).

When comparing human and bovine teeth as a substrate, histochemical and comparative anatomical studies have revealed that all mammalian teeth are essentially similar (Swartz & Phillips 1955, Bowen 1965, Fusayama *et al.* 1979). Natural teeth were preferred for the preparation of the specimens for this study and it seems to represent the best possible option to simulate clinical situations for root filled teeth (Newman *et al.* 2003). Previous studies have reported their use as an acceptable means to research post systems (Saupe *et al.* 1996, Mendoza *et al.* 1997, Sidoli *et al.* 1997, Katebzadeh *et al.* 1998). All roots were filled, and care was taken to create standard cores. The manufacturer's instructions were followed carefully in fabrication of dowels to ensure that the laboratory procedures were the same as those used clinically. In

this study, complete crown coverage was not used. Influence of fatigue loading and thermal cycling on fracture resistance was also not investigated. Further laboratory studies should consider the impact of completed crowns and fatigue factors on strength.

Resin cement was used for luting the posts into the canals. Bonded resin cements are recommended for use in children in roots with thin walls such as immature teeth or those with extensive caries because of their potential to increase the fracture resistance of teeth (Katebzadeh *et al.* 1998). Panavia F was the preferred material used for luting the fibre-reinforced posts in all samples because previous studies reported that Panavia F resin cement dramatically increased the load capability (Naumann *et al.* 2006). In groups resin + glass fibre post and composite corono-radicular restoration, Clearfil Majesty Esthetic (Kuraray) was the chosen composite material to form part of the restoration. For the matching of same brand materials, Clearfil SE Primer and Bond were used as an adhesive. The same primer and bonding material were preferred for all other groups for standardization.

Cast metal post-cores placed in thin-walled roots have been linked to root fracture (Tjan & Whang 1985). On the contrary, preference for fibre-reinforced composite posts that have a modulus of elasticity similar to that of dentine, which facilitates stress dissipation, may be a good alternative (Boschian Pest *et al.* 2002). For this reason, fibre-reinforced composite post systems were used to reinforce the root walls in this study and compared with cast posts.

On the basis of this study, fibre-reinforced composite posts created less fracture resistance than cast post and cores. These findings are in agreement with those of Maccari *et al.* (2007) who reported that the lower fracture strength of fibre-reinforced composite posts compared with the values for cast metal posts might be attributed to the displacement or fracture of the resin cement layer, composite core, or resin post during mechanical testing (Maccari *et al.* 2007).

There was no statistically significant difference between the different fibre systems used for posts. Although the types of post systems used were not the same, condensing of posts and composite into the dowel spaces was accomplished using the same approach. All these aesthetic post core systems closely adapted to root canal morphology, all the chosen materials had close modulus of elasticity and their mechanical characteristics approximated each other (Boschian Pest *et al.* 2002).

The results of this study differ from those of Newman *et al.*, who compared the fracture resistance of pre-fabricated posts (Fibre Kor and Luscent anchors) and Ribbond in both 'narrow' and 'flared' canals. They concluded that Ribbond was less fracture-resistant than Fibre Kor in the flared canals. However, all the post systems used in this study were adapted to the root surface using filled resins, and a minimal amount of luting cement was used. The other factors that might affect the mechanical behaviour of the system were the volume of the core and the dentine bonding area on the coronal portion of the posts. These influences should be considered in future research.

In this study, although there was no significant difference between the different type of fibre-reinforced composite (FRC) post groups, large canals were less resistant than narrow canals. This finding supports the opinion that the fracture strength of root filled thin-walled teeth is affected by remaining dentine thickness. The fundamental importance of preserving the remaining tooth structure to provide strength and resistance to fracture after both endodontic therapy and post-space preparation has been reported previously (Sorensen & Martinoff 1984). Dentinal wall thickness is stated to be directly proportional to the ability to withstand lateral forces (Assif & Gorfil 1994). Tjan & Whang (1985) found that more than 1 mm thickness of the labial dentine wall of the post channel is required to prevent root fracture under horizontally directed force. The volume of dentine remaining after tooth preparation was most relevant to tooth strength according to Sedgley & Messer (1992). Generally, fibre-reinforced composite posts with remaining dentine thickness of 2.0 mm were more fracture-resistant than the other two groups. However, the cast post group with remaining dentine thickness of 1.0 mm and 1.5 mm showed higher fracture strength than the cast post group with remaining dentine thickness of 2.0 mm. This finding might be explained by the increasing diameter of the post and rigidity of the material. The large canals allow the placement of thick metal, which resists higher fracture load compared with narrow canals. However, increased rigidity of the metal may lead to catastrophic failures in excessive loads. Again these factors should be considered in future research.

Furthermore, the load characteristics, the other specialities of cast and fibre-reinforced composite post systems, should also be thoroughly considered before clinical use. Whilst cast metals enable fabrication of post and cores from the same material as a single unit, overall aesthetic rehabilitation is possible in FRC systems. Despite higher load failure modes, cast systems may predispose the tooth to root fracture (Cheung

2005) In case of trauma, rigidity may cause catastrophic failures of roots (Sirimai *et al.* 1999, Cheung 2005) and removal of the post when compared with fibre-reinforced composite systems may be problematic in re-treatments (de Rijk 2000). There is a direct relationship between post length and retention in cast posts. Insufficient post length causes uneven distribution of stress in tooth structures. There should be no undercut in post space preparation and flaring should be assessed thoroughly. Obtaining retention of more than a single canal is easier in fibre-reinforced composite posts. Post adaptation is also easier in fibre-reinforced composite posts and there is no laboratory work.

Under the circumstances of this study, even though restoration with a composite corono-radicular material is practical and economical, fibre-reinforced composite post and core systems yielded more resistance without a significant difference.

Despite satisfactory clinical results of fibre-reinforced composite posts (Mannocci *et al.* 2002, 2005), there is a need for more controlled clinical follow-up studies for the choice of either all composite restorations or FRC posts.

Conclusion

Given the limitations of this study, the following conclusions can be drawn.

1. Fracture strength with flared roots did not vary according to the type of fibre-reinforced composite posts. However, teeth restored with cast posts had higher fracture strength than FRC posts.

2. Shear strength of the root filled thin-walled resin dowel and core restored teeth might be affected by the remaining dentine thickness. Fibre-reinforced composite posts with a remaining dentine thickness of 2.0 mm were more fracture resistant than the other two groups (1.0 mm and 1.5 mm), although it did not reach statistical significance.

3. Composite corono-radicular restorations yielded lower load values than different fibre-reinforced composite restorations, however, the difference was not statistically significant.

4. Cast posts with narrow canals were less fracture resistant than cast posts with flared canals.

Acknowledgements

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